Assessment

Forest Plan Revision

Draft Invasive Plants Report

Prepared by:

Susan Lamont
West Zone Vegetation Manager

and

Kim Reid
Invasives Program Leader

for:
Custer Gallatin National Forest
November 29, 2016

Contents

Introduction

Non-native invasive plants have the potential to alter the ecosystem by displacing native plants. Invasive plants have been found to impact wildlife habitat by decreasing the amount of forage, change fire frequency by forming dense stands of flashy fuels, change soil characteristics by altering soil nutrients, and change grassland, shrubland, open woodland, and riparian ecosystems by out-competing native plants.

There are many different ways invasive plants spread across the landscape. For example, seeds are spread by the wind, by animals (wildlife and domestic) and by water transport. However, people are the main vector for spreading invasive plants on the Custer Gallatin National Forest. The majority of weeds on the Custer Gallatin National Forest are within 2,000 feet of a disturbance (roads, trails, recreation sites, developed facilities, and other activity areas; see Table 5). Areas with high levels of disturbance tend to have more weeds than undisturbed areas. The forest plan can influence which areas are disturbed, what prevention measures become standard practices, and how much emphasis will be placed on weed control.

Process, Methods and Existing Information Sources

Invasive plants are aggressive and have the potential to spread rapidly across landscapes. A large portion of the Custer Gallatin National Forest has not been surveyed for invasive plants due to limited resources and remoteness. The area survey tends to emphasize disturbed areas more than undisturbed areas. Most of the remote areas have not been surveyed, at least in part because they are less prone to infestation.

The Custer Gallatin uses the Montana and South Dakota noxious weed lists, county weed lists, and other lists of non-native plants of concern to identify which invasive species to manage across the national forest, as well as project-specific invasive plant risk assessments that are conducted (see Appendix B). Risk assessments help identify threats to native vegetation as a result of project-related ground disturbance and invasive species known to occur within or near a project area. They also prescribe mitigation measures to reduce these threats. As project areas are surveyed, new infestations are inventoried.

The Custer Gallatin Invasive Plant database and spatial layer used in this analysis is the best available information at this time because it is collected locally. Even though the data may be incomplete, it is the most extensive inventory available for the local condition. Data is updated when new infestations are discovered. The population size, shape and density likely changes annually but this is not necessarily reflected in the inventory.

The Forest Service's Northern Region vegetation mapping (VMAP) spatial layer and database was used in the analysis to identify vegetation types in the habitat vulnerability analysis. VMAP is the most current and accurate description of the existing vegetation for the Custer Gallatin. It was developed in 2013 and ground verified in 2014. Since there are no other readily available sources, VMAP is the best available information.

To assess ecosystem drivers and trends, a literature review of the best available science was conducted.

To estimate the number of weed-infested acres currently on the national forest, the Custer Gallatin Invasive Species database and spatial layer was queried using our GIS (Geographic Information System). The spatial layer was "clipped" to include only populations within the national forest boundary, to be consistent with the spatial boundary for this assessment. The GIS query selected the current data (excluding eradicated sites). The mapping protocol for weed inventory uses a polygon around the entire weed infestation for each species which is referred to as the gross area; the percentage of infested area within the gross acres is estimated and used to calculate the infested area. For the overall footprint of weed occurrence, the gross area was "dissolved" in GIS to remove the overlapping polygons (thus avoiding double-counting acres) that can occur when multiple weed species are in the same location. However, when addressing species-specific information in this report, acreage reported may duplicate other species' acreage since their infestations often overlap. Therefore, species-specific totals could be higher than the overall gross acreage footprint.

The Invasive database was queried for population level in 2006 and then again in 2016. This was used to show inventoried population levels at two different times. This database was also used to summarize weed acreage by species for each of the five analysis areas (Gallatin, Madison and Beartooth Mountains; Bridger, Bangtail and Crazy Mountains; Pryor Mountains; Ashland Ranger District, and Sioux Ranger District).

To identify areas vulnerable to invasive plants; GIS queries used the Forest Service Northern Region's VMAP vegetation spatial layer and database to map vulnerable habitat within each of the five analysis areas. Knowing where vulnerable areas are located (see Appendix A) can help determine the best mitigation measure and most appropriate level of control. The GIS query selected habitat types where invasive plants have been found to be very aggressive, based on published studies and professional experiences (Mantas 2003). There are currently 33 invasive plants of concern, including both terrestrial and aquatic species within the Forest.

In this assessment, vulnerable areas are distinguished by canopy cover, elevation, and association with riparian areas:

- Most of these plants grow in sunlight, however, orange hawkweed is a notable exception and will grow in partial shade – up to 60 percent canopy cover (Hoffman 2016).
- Most weeds grow at elevations less than 9,000 feet. Based on the Custer Gallatin Invasive database, only 99 of the 57,612 infested acres grow above this elevation (0.2 percent).
- Most aquatic invasive plants require sunlight to flourish (UF/IFAS 2016). Clear water quality on the Custer Gallatin allows aquatic weeds to grow in water 10 to 30 feet deep and along shorelines. There are now eight aquatic species on the Montana noxious weed list; of those, four are within or very near to the national forest boundary (Eurasian water-milfoil, curly leaf pond weed, purple loosestrife and tamarisk).

Using these parameters, the number of vulnerable acres for each of the five analysis areas is summarized in Table 3. Maps of vulnerable habitat are provided in Appendix A of this report.

Spatial and Temporal Scale of Assessment

A forest plan provides direction and guidance about forest management activities and this assessment is concerned with how those activities may promote invasive plant establishment and spread. Although invasive plants can be spread across boundaries, most of the impacts from forest plan management of invasive plants are within the national forest boundary. The spatial boundaries for this assessment are limited to lands within the Custer Gallatin National Forest proclaimed boundary.

The temporal scale is from the turn of the 20th century to 50 years into the future. Unrestrained sod-busting, economic depression, and increasing weed density during the first four decades of the20th

century created many conditions conducive to weed invasion. In addition, shipments and transportation systems continued to bring in new weed species. Fifty years into the future is the timeframe used for projected trends.

Current Forest Plan Direction

The Custer and Gallatin forest plans are similar with respect to invasive plants and noxious weeds. Both forest plans direct managers to use an integrated pest management program to control noxious weeds and to work with partners (other agencies and adjacent land owners) to control weeds. Differences between the two forest plans include the following:

- The Custer forest plan prioritizes control based on size of infestation; focused on eliminating new starts and small infestations. For bigger patches, containment or reduction in size is specified (Custer forest plan, pp. II-3 and II-24). This element of the forest plan provides consistent direction for the strategy and priority of treatment areas across the national forest.
- The Gallatin forest plan standard states that funding for weed control on disturbed sites will be provided by the resource that causes the disturbance (Gallatin forest plan, 2015 amended, p. II-32). This forest plan standard provides incentive for all resource areas to minimize the spread of weeds and to help fund weed control.

Prioritizing treatment areas and control strategies have been effective only to the extent that resources have been available to implement them. There is still a trend of increasing weed introduction and spread given limited resources for prevention and treatment. Resource areas that cause the disturbance have not consistently funded weed control on disturbed sites.

For compliance with the National Environmental Policy Act, forestwide environmental impact statements for weed management were completed on both national forests (Custer National Forest 2006, Gallatin National Forest 2005).

Existing Conditions

Definition of Terms

The term “invasive plants” (both terrestrial and aquatic) refers to non-native plants that have the potential to cause ecological or economic harm. For the purposes of this assessment, invasive plants include Montana and South Dakota State-designated noxious weeds, regulated plants, and other plant species considered invasive. A species is considered invasive if:

1. it is nonnative to the ecosystem under consideration, and
2. its introduction causes, or is likely to cause, economic or environmental harm, or harm to human health (Executive Order 13112, 1999).

Invasive plants include noxious weeds and other weeds of concern identified by the Custer Gallatin National Forest. Similarly, noxious weeds are legally declared by individual counties and states (both Montana and South Dakota). Management of weeds is required by state law.

Weed Management Program

Forest Service policy (FSM 2900) was issued to comply with Executive Order 13112 and address adverse impacts from invasive species. The intent of the policy is to ensure that all forest management activities are designed to minimize the possibility of establishment or spread of invasive species on National

Forest System lands, or to adjacent areas. Spread vectors, environmental factors, and pathways that favor the establishment and spread of invasive species in aquatic and terrestrial areas are determined and management practices are designed to reduce or mitigate the risk for introduction and spread of invasive species in those areas.

The goal of invasive species management is to prevent new infestations and manage (contain, reduce, and eradicate) infestations currently established on the national forest through control measures. Methods to control the spread of invasive species include prevention, treatment, and containment. Methods used to prevent invasive species from being introduced and spreading into new areas include closing infested areas to travel, washing vehicles and equipment prior to entering or leaving an area, using weed-free seed and straw mulch for revegetation, and requiring weed seed-free forage for stock use on national forest lands. Another key strategy for preventing further spread or introduction of invasive plants into weed-free areas is the use of an early detection and rapid response tactic. This tactic focuses on the discovery and early treatment of small isolated infestations. This results in greater control when the infestations are small, and makes true eradication more feasible.

The most effective, economical, and ecologically sound approach to managing invasive plants is to prevent their invasion in the first place (Clark 2003). When infestations are detected and treated early there is a far greater chance for eradication, and costs associated with management are lower. Lack of early treatment typically leads to the development of major weed problems (Hobbs and Humphries 1995). Large infestations are often logistically and economically difficult to manage. Since large infestations are highly visible, there tends to be political pressure to treat those areas even though this may not be the most efficient use of limited resources and often results in the lost opportunity to treat smaller infestations, which is much more effective at slowing the spread of weeds (Fried et al. 2013). When weed distribution and density levels become too great, eradication is not feasible and treatment tactics focus on reducing density or containing the infestation with perimeter treatments.

Treatments such as manual (hand pulling), mechanical (mowing), biological (insects), agricultural (revegetation of disturbed areas), and chemical (herbicides) methods are used to manage infestations. Treatment by sheep or goats have typically not been used due to concerns regarding transfer of disease between domestic and wild animals, and concerns about predation on the Montane units of the assessment area.

Factors influencing the order of treatment priority include the species to be controlled, its rate of spread, infestation size, habitat, and location. Species vary in their reproduction methods, and weeds that reproduce vegetatively require treatment methods different from those used for species that only reproduce by seed. Some species have higher rates of spread than others; widespread species take more resources to control than new or potential invaders. Small infestations are possible to eradicate, while large infestations are more difficult to eradicate and are typically prioritized for management through containment. Habitat type influences the survival of an invasive plant and of native plants that need to compete for resources, and some habitat types are more vulnerable to invasive plants than others.

The location of infestations is important. Areas of high public use, such as roads, trails, campgrounds, trailheads and other recreation sites are a high priority since these areas receive a lot of visitor use and are typically at greater risk of invasion or, in cases where invasive plant species are already present, function as seed sources for introduction of those species into less infested areas. Other areas that are remote or are less disturbed natural areas (such as wilderness and research natural areas) and areas considered to be nearly weed free are also a high priority for treatment. Although these areas require higher investment and effort to access and treat, they are considered a high priority because they are usually not yet heavily infested or are nearly weed-free.

The Custer Gallatin National Forest implements an integrated invasive species management process for all approved management actions. The two environmental impact statements that separately analyzed weed management alternatives on the Custer and Gallatin National Forests in 2005 and 2006 evaluated the effects of treating invasive plants and identified an adaptive and integrated pest management strategy to control and reduce the presence of invasive species. The common weed management approach given in these documents can be summarized by the following four key elements: prevention, detection, control and management, and restoration and rehabilitation. The Custer Gallatin National Forest has a strong commitment to work with a variety of partners (such as nongovernmental organizations, counties, and state agencies) to accomplish these treatments.

Management activities for aquatic and terrestrial invasive plant species are based upon an integrated pest management approach on all areas within National Forest System lands, prioritizing prevention, early detection, and rapid response actions as necessary. Control and containment of invasive plant species is another tactic used to minimize the spread of weeds. Collaboration continues to be an important part of the overall program to increase public awareness of the invasive species threat, and to promote a better understanding of integrated activities necessary to effectively manage aquatic and terrestrial invasive species.

The main control emphasis in the weed management program is herbicide treatment of existing weeds. The Custer Gallatin treats approximately 3,000 to 4,000 acres of weeds with herbicide per year. Releases of biological control insects have also been used. The acreage treated varies annually. Most funding for this program comes from congressionally appropriated funds; additional funds are obtained through grants from outside the Forest Service. Priority treatment areas focus on new invader species, small infestations and major vector areas (trailheads, road side, campgrounds, and future project areas where ground disturbance is likely).

Another area of emphasis is weed prevention. Associated activities include washing and inspecting off-road heavy equipment, design activities to avoid disturbing exiting weed infestations, use of weed-free seed and gravel sources, and conduct of follow up weed treatments and surveys after site disturbances. These are common mitigation measures for projects that involve soil disturbances.

Other management activities include monitoring for new weed infestations and public awareness campaigns.

Existing Condition

Nonnative invasive plant species, also called noxious weeds or invasive plant species, have disrupted natural processes on nearly 100 million acres in the United States and are spreading at an estimated rate of 14 percent per year (USDA APHIS 2001). On National Forest System lands in the United States noxious weeds have been estimated to be increasing at 8 to 12 percent per year (USDA Forest Service 1998). The most widespread weed in Montana is spotted knapweed. It has been estimated that spotted knapweed has increased at a rate of 27 percent per year (Sheley et. al 2011).

Currently there are 53 invasive species listed for the Montana and South Dakota portions of the Northern Region, including lists from states, counties, and other national forests (see Appendix B for the entire list). Of these, 33 species are currently known to be on the Custer Gallatin National Forest. The status of each invasive plant species is considered when determining the appropriate management strategy and priority. Some of the most common species are spotted knapweed, Canada thistle, hounds-tongue, nodding thistle, leafy spurge, cheatgrass, yellow toadflax, and Dalmatian toadflax. The species of highest priority for treatment and containment are spotted knapweed, leafy spurge, toadflax species (yellow and Dalmatian), orange and meadow hawkweed, and those species that are on the State noxious list but not currently present on the Custer Gallatin National Forest (for example, yellow starthistle). Reduction of particularly aggressive species is critical for the protection of intact plant communities and associated habitats. Avoiding the establishment of additional species is equally important in the maintenance of healthy landscapes.

There are some areas where nonnative species such as timothy grass, smooth brome, Kentucky bluegrass, and crested wheatgrass occur. Due to old reseeding practices on a minor part of the landscape, some areas have smooth brome (montane and pine savanna areas) or crested wheatgrass (pine savanna). Due to adjacent land activities during settlement and historic grazing overuse at the turn of the 20th century, some areas have large amounts of Kentucky bluegrass (montane and pine savanna areas), and timothy grass (montane) as part of the landscape.

Eradication is likely not feasible for many of the invasive species. Although there are large infestations of species such as Canada thistle and hounds-tongue, these species are not typically targeted for eradication due to their abundance on the national forest, in the state, and in the West at large. The management approach for these widespread species is typically focused on containment; with eradication efforts and resources typically reserved for smaller isolated infestations and species with lower abundance across the Custer Gallatin National Forest. Some exceptions may apply to specific project areas depending on local conditions.

Species that have limited occurrence, either in number of acres or number of sites, are considered new invaders. New invaders on or near the Custer Gallatin include hawkweeds (both orange and meadow), tamarisk, Eurasian water-milfoil, purple loosestrife, blueweed, knotweed, yellow starthistle, and dyer's woad. Table 1 displays the amount of inventoried weeds (infested acres), by species for each landscape area.

Presence and amount of invasive species and noxious weeds is a key indicator for overall ecosystem health. The 2016 watershed condition framework assessment identified that most noxious weeds affect less than 10 percent of each individual watershed (sixth code hydrological units). However, six watersheds were identified as having a noxious weed footprint of between 21 and 54 percent of the watersheds. Weeds in Lower Mill, Bloom Creek, Paget Creek, and Horse Creek Watersheds were exacerbated by wildfires in those areas. Some weeds in these areas have been treated, but seed banks likely exist and influence overall footprint for weed risk. As infestations increase in size, a containment strategy is typically used to treat the periphery of the area rather than attempting eradication which is generally not feasible given limited resources. The six watersheds are outlined in Table 2 and Figure 1 and Figure 2.

Table 1. Acres of weeds (infested acres) for each landscape area

Species	Madison, Gallatin, Beartooth Mtns	Bridger, Bangtail, Crazy Mtns	Pryor Mtn	Ashland	Sioux
Artemisia absinthium	<1				87
Hoary alyssum (*Berteroa incana*)	754	1	<1		
Cheatgrass (*Bromus tectorum)*	2,019				
White top *(Cardaria dradba)*	36	<1	<1		
Nodding thistle *(Carduss Nutans)*	3,408	2,463			5
Spotted knapweed *(Centaurea biebersteinii)*	8,003	275	769	5,607	689
Diffuse knapweed *(Centaurea diffusa)*	1				
Russian knapweed *(Centaurea repens)*	<1	<1		19	<1
Oxeye daisy (*Chrysanthemum leucanthemum)*	738	233	24		
Canada thistle (*Cirsium arvense)*	7,118	1752	871	37	4,148
Bull thistle *(Cirsium vulgare)*	1,341	201			7
Poison hemlock *(Conium maculatum)*	11				
Field Bindweed (*Convolvulus arvensis)*	160		552		51
Houndstongue (*Cynoglossum officinale)*	6,360	2515	403	2	368
Leafy spurge (*Euphorbia esula)*	578	96	3	6,350	491
Orange hawkweed (*Hieracium aurantiacom)*	94	21			
Meadow hawkweed (*Hieracium sps)*	46		<1		
Black henbane (*Hyoscyamus niger)*	100				
St. John's wort (*Hypericum perforatum)*	62	15		12	
Field scabiosa (*Knautia arvensis)*	5	0.01			
Dalmatian toadflax (*Linaria dalmatica)*	796	0.04	418		
Yellow toadflax (*Linaria vulgaris*)	1,672	481			
Sulfur cinquefoil (*Potentilla recta)*	350	74			<1
Tall buttercup (*Ranunculus acris*)	20				
Common tansy (*Tanacetum vulgare)*	308	50			
Tamarisk (*tamarix sp*.)	<1			<1	
Common mullein *(Verbascum Thapsus)*	648	166		1	12
Sum infested acres 2016*	**34,766**	**8,348**	**3,046**	**12,032**	**5,863**

* 64,055 total infested acres which includes overlapping species-specific infestations, (57,612 total footprint without overlapping acres)

Table 2. Percent of watershed with noxious weed cover

Landscape Area	Watershed Number (HUC 12)	Watershed Name	Watershed NFS Acres	Gross Infested NFS Acres	Percent NFS Watershed with Noxious Weeds
Madison, Gallatin, Beartooth Mountains	100700010902	Yellowstone River-Reese Creek	7,556	2,430	32%
Madison, Gallatin, Beartooth Mountains	100700020305	Lower Mill Creek	14,353	7,716	54%
Pryor Mountains	100800140401	Sage Creek-North Fork Sage Creek	15,655	3,302	21%
Ashland	100901020203	Otter Creek-Horse Creek	17,957	6,819	38%
Ashland	100901020207	Paget Creek	8,702	2,597	30%
Ashland	100902070206	Bloom Creek	24,496	5,257	21%

NFS = National Forest System

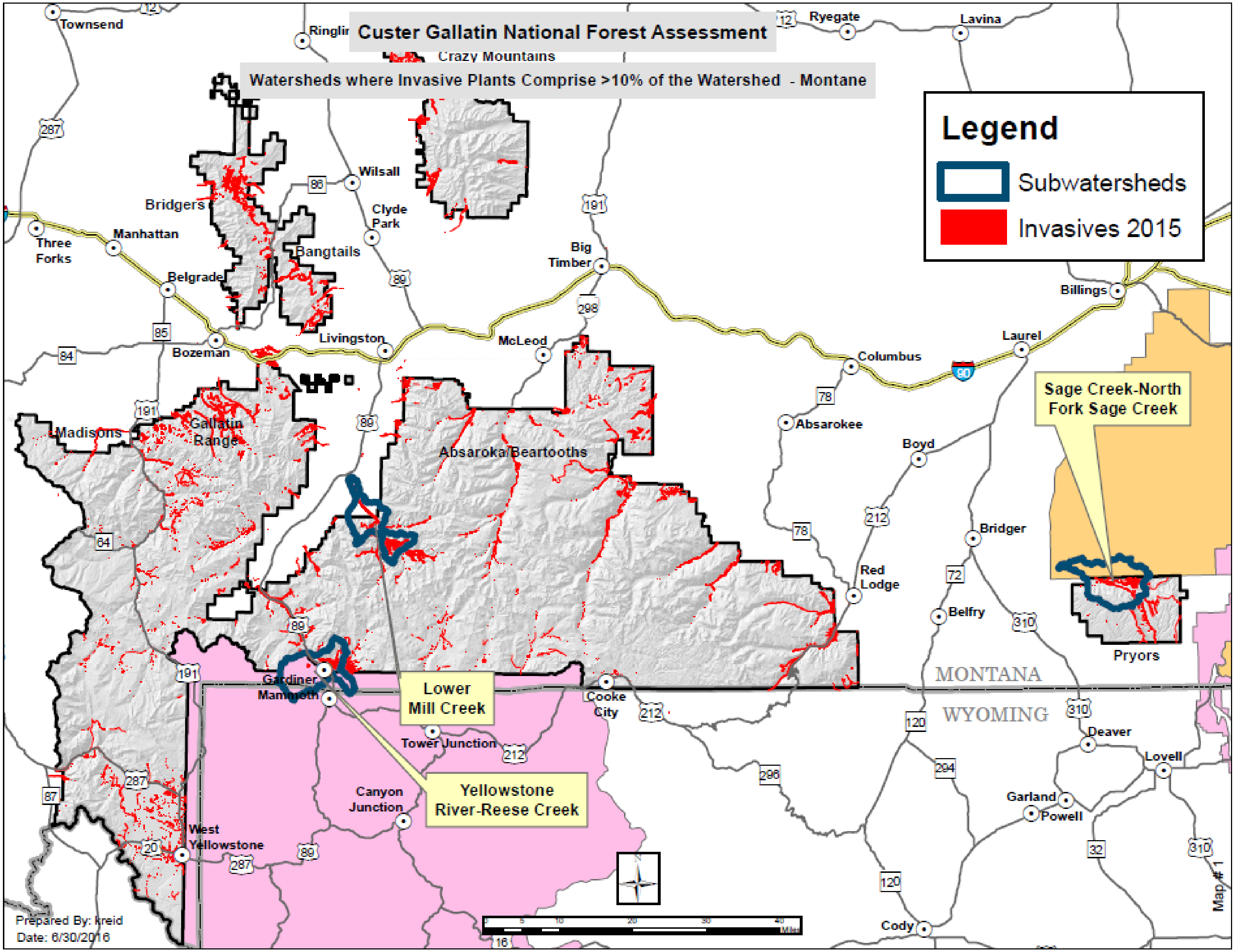

Figure 1. Watersheds with greater than 10 percent invasive plant species in montane areas

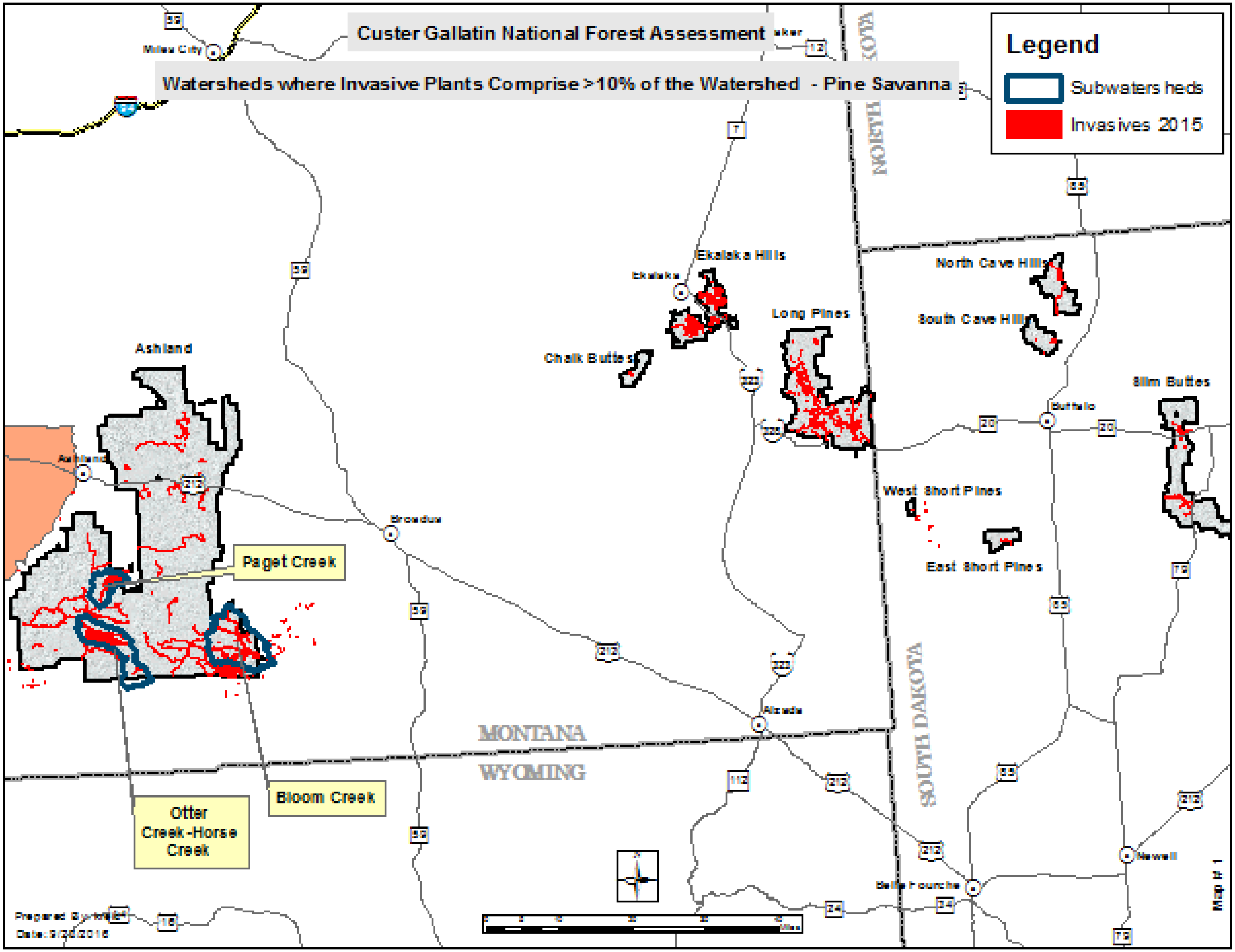

Figure 2. Watersheds with greater than 10 percent invasive plant species in pine savanna areas

Another useful attribute for describing the current weed infestation problem is to consider the number of acres infested compared to the potential acres of vulnerable habitat. Each weed species has a preferred habitat where the weeds will thrive and out-compete the native plants. Given the parameters of canopy cover, elevation and aquatic and riparian habitat (as discussed in the Process and Method section above), almost all areas are vulnerable except for dense forest (canopy cover greater than 60 percent), and areas above 9,000 feet.

Vulnerable areas may develop large infestations of weeds that alter ecological processes or site productivity. Conversely, areas not vulnerable have few weeds, and weeds that are present are generally limited to highly disturbed areas. Table 3 lists the total acreage for each area, the acreage of vulnerable habitat, and the current footprint of weed acreage. These numbers assume that areas with canopy cover greater than 60 percent will not change over time. If the canopy cover is reduced (by fire, insect outbreak or timber harvest) then the percent of vulnerable habitat will increase until the forest canopy regrows. In areas with high percentages of vulnerable habitat, there are few natural barriers to slow the spread of weeds. In the Pryor, Ashland, and Sioux areas, once invasive plants become established the plants can more easily spread throughout those areas. See Appendix A for maps of infestations in proximity to vulnerable areas by landscape area.

Table 3. Vulnerable habitat (all terrestrial and aquatic habitat) less than 9,000 feet and less than 60 percent canopy cover, and current footprint of weed acres

Vulnerable & Infested Habitat Acres	Madison, Gallatin, Beartooth Mtns	Bridger, Bangtail, Crazy Mtns	Pryor Mtns	Ashland	Sioux
Total Acres	2,343,912	314,612	77,943	501,466	176,335
Acres Vulnerable habitat under 9,000 feet and less than 60% canopy cover	908,165 38% of total area	187,214 59% of total area	59,420 76% of total area	496,544 99% of total area	174,546 99% of total area
Acres Infested footprint	27,503 acres 3% of vulnerable area	4,485 acres 2% of vulnerable area	2,025 acres 3% of vulnerable area	16,122 acres 3% of vulnerable area	7,477 acres 4% of vulnerable area

Other special areas on the Custer Gallatin where the presence of invasive plants may significantly compromise ecological integrity include wilderness areas, Forest Service recommended wilderness areas, inventoried roadless areas, research natural areas, botanical special interest areas, and areas of important wildlife habitat (such as sage grouse habitat and elk winter range).

Table 4 lists the current level of weeds for each of these areas.

Table 4. Acres of inventoried invasive weeds in wilderness areas, roadless and recommended wilderness areas, research natural areas, elk winter range, and sage grouse habitat[1]

Infested Areas	Madison, Gallatin, Beartooth Mtns	Bridger Bangtail, Crazy Mtns	Pryor Mtn	Ashland	Sioux
Weed infested wilderness, infested acres	Absaroka Beartooth 2,123 acres, Lee Metcalf 56 acres	N/A	N/A	N/A	N/A
Weed infested roadless and recommended wilderness infested acres	Burnt Mountain 14 acres, Dry Canyon 3 acres, Fishtail Saddleback 1 acre, Line Creek Plateau 35 acres, Reef 14 acres, Beartooths less than 1 acre, Black Butte 11 acres, Cabin Creek Wildlife Mgt Area 41 acres, Chico Peak 44 acres, Crazy Mtn 525 acres, Gallatin Fringe 65 acres, Hyalite Porcupine Buffalo Horn WSA 186 acres, Lionhead Roadless 45 acres, Lionhead Recommended 3 acres Madison 276 acres, North Absaroka 5,653 acres, Red Lodge Hellroaring 408 acres	Bridgers 92 acres	Lost Water Canyon 17 acres	King Mtn 9 acres	N/A
Acres weed infested research natural and special interest areas/total	Line Creek RNA 8 acres, Sliding Mountain RNA 2 acres, Black Sands Spring SIA 1 acre, East Fork Mill Creek RNA 5 acres, Obsidian Sands RNA less than 1 acre	Bangtail SIA 447 acres	Lost Water Canyon RNA 1 acre	Poker Jim RNA no acres inventoried	N/A
Weed infested elk winter range[2] acres/ total winter range acres	Big Timber – 2% (1643/72542) Gallatin Madison – 2 % (1655/76635) Hebgen – 3% (2454/76635) Paradise Gardiner- 4% (7064/178487) Beartooth 6% (4349/70500)	Bridgers <1% (230/27222) Crazy <1% (116/19872)	No acres were identified as winter range	Ashland 6 % (2816/ 48967)	Sioux (MT) 6 % (1020/ 17437)
Sage grouse core and general habitat[3]	7% of sage grouse general habitat is infested (201 gross /2776 General)	No infestations recorded in the 4 ac of general habitat	<1% of sage grouse general habitat is infested (70 gross /27392 General)	3% of sage grouse general habitat is infested (3058 gross /101290 General)	>1% of sage grouse general habitat is infested (28 gross /8424 General) 6% of sage grouse general habitat is infested (96 gross /1522 General)

1. All weed infested acres were dissolved so overlapping areas were not double counted.
2. GIS data was available for the elk winter range defined by Montana Fish Wildlife and Parks, as such, the South Dakota portion of the Sioux Ranger District was not included in this part of the analysis.
3. The sage grouse core and general habitat as defined by Montana Fish Wildlife and Parks and South Dakota Game Fish and Parks.

A complete list of individual weed species occurring in wilderness, roadless, research natural areas, and special interest areas is given in Appendix C.

Since each of the five areas of the Custer Gallatin National Forest is distinct with respect to invasive weeds, a more detailed description is provided below.

Madison, Gallatin and Beartooth Mountains

This area includes five mountain ranges, and includes a total 2,343,912 acres; about 38 percent of this area is vulnerable to invasive plants with 3 percent being infested. Large infestations of invasive plants occur mostly in disturbed areas and along motorized routes. Other disturbances are from large forest fires, recreational activities (campsites, trailheads, developed recreational areas, fishing access), timber harvest, and livestock grazing. New invaders include orange hawkweed, blueweed (adjacent to the national forest), dyer's woad (infestations eradicated), field scabiosa, tall buttercup, Eurasian water-milfoil (adjacent to the national forest), tamarisk, and yellow starthistle (infestation eradicated).

Bridger, Bangtail, and Crazy Mountains

This area includes three mountain ranges and includes 314,612 acres; about 68 percent is vulnerable habitat with 2 percent being infested. Large infestations of thistles, hounds-tongue, spotted knapweed, and oxeye daisy occur in disturbed areas. Many of the weeds are on old logging areas, livestock allotments and on lands acquired through land exchanges. New invaders include orange hawkweed, leafy spurge, and St. John's wort.

Pryor Mountains

The Pryor Mountains includes 77,943 acres, and 76 percent is vulnerable habitat with 3 percent being infested. Most common weed species include spotted knapweed, Canada thistle, hounds-tongue, leafy spurge, field bindweed and Dalmatian toadflax. New invader species include meadow hawkweed and oxeye daisy.

Ashland District

The Ashland Ranger District includes 501,466 acres and 99 percent is vulnerable habitat with 3 percent being infested. Most common weed species include spotted knapweed, leafy spurge, Russian knapweed, and St. John's wort. Large forest fires caused large increase in spotted knapweed and leafy spurge. New invader species include tamarisk. There are no "quarantine" type pastures that livestock are placed in before moving onto the national forest. The leafy spurge that now infests the southern part of the Ashland Ranger District could be contributed by livestock, just as much as wildlife or human activity.

Sioux District

The Sioux Ranger District includes 176,335 acres and 99 percent is vulnerable habitat with 4% being infested. Infestations of Canada thistle, leafy spurge, spotted knapweed, absinthium and hounds-tongue occur in disturbed areas. New invader species include sulfur cinquefoil.

Key Benefits to People

Invasive plants cause undesirable ecological impacts. The plants arrived in this country with few or no natural pathogens or insects; consequently, they increase in density and out-compete native plants. Numerous studies describe the ecological impacts of invasive weeds when they are at high density levels. Most infestations on the Custer Gallatin are at low densities but there are occasional high density infestations. Regardless of density, weeds are very expensive to control, and native plants are difficult to restore.

Ecological impacts of weeds at high density levels include a reduction in forage for livestock and wildlife. Research has indicated that elk will use knapweed and cheatgrass, but native grasses make up the majority of the diet (Kohl et al. 2012). Herbicide treatment of spotted knapweed increased perennial grass biomass by 7.5 times where knapweed density averaged 36 mature plants per square meter – more than 60 percent canopy cover (Sheley et al. 2000). This is an indication of the amount of native grass that is lost with high density levels of spotted knapweed.

High density levels of spotted knapweed have been found to increase surface run off and stream sediment levels, and to change soil nutrients. For example, changes in phosphorus were detected when spotted knapweed canopy cover was 60 to 80 percent (Thorpe et al 2006). Likewise, research studies found an increase in surface runoff and sediment in sites of heavy knapweed infestation (90 percent) compared to sites in which native grasses dominate (Lacey et al. 1989). The runoff was 56 percent higher and the stream sediment yield was 196 percent higher on sites dominated by spotted knapweed compared to sites dominated by native bunchgrasses. Water infiltration was greater on sites with grasses than on sites with spotted knapweed.

Weeds can also change the frequency of wildland fires. Cheatgrass has been found to increase fire frequency in areas where it is abundant (Penn State 2012, Balch et al. 2012). The more frequent fires are causing populations of native grasses and shrubs to decrease and the cheatgrass to increase.

High densities of aquatic invasive plants can decrease the quality of fishing and swimming areas, and such infestations are beginning to appear in the Custer Gallatin National Forest area. Eurasian water milfoil will form dense mats of vegetation that provide poor habitat for waterfowl and fish, alter water quality by raising pH, decrease oxygen, increase water temperature, and limit access for fishing and swimming (http://www.ecy.wa.gov). This plant was found in the Madison River and Jefferson River in 2010 (http://invader.dbs.umt.edu). Curly leaf pond weed is another aquatic invasive weed that has similar ecological impacts as Eurasian watermilfoil, and it was found in Hebgen Lake in 2011. Purple loosestrife was first found in Montana in 1992 in the western part of the state; now it is present in Meaghen, Carbon and Rosebud Counties. Tamarisk is yet another invasive weed that forms thick clumps of vegetation adjacent to stream banks; the plant limits access to streams and displaces native plants (http://www.ecy.wa.gov). Tamarisk was first discovered in Montana in 1971 and now is present in more than eight counties; small infestations were found on both the Ashland and Beartooth Ranger Districts.

The Custer Gallatin National Forest spends $300,000 to $400,000 per year on weed detection, prevention, and control. The annual treatment is 3,000 to 4,000 acres per year, or 5 to 7 percent of the existing weed population. Given the limited funding levels, the Custer Gallatin has developed a management strategy that gives priority to new invaders, and secondary priority to treatment of areas impacted by construction and vegetation projects, roadsides, recreation sites, and areas with specific funds designated for treatments. Many high value remote areas, such as wilderness or research natural areas have not been treated consistently typically due to logistical considerations.

Trends and Drivers

Over the past 10 years, infested acreage has increased substantially. Some of the increase is due to an increase in species listed as noxious by the State. In 2006 there were 27 State-listed weeds; in 2016 there are 33 noxious species plus 5 regulated species[1] (see Appendix B). Some of the increase is due to a revised inventory that covered more land, and some of the increase is due to more extensive infestations. Regardless of the cause of the increase, the Custer Gallatin's infestations have doubled in the last 10 years. Table 5 and Figure 3 show the gross acreage of weeds in 2006 and 2016. The Bridger, Bangtail and Crazy Mountains have the largest percent increase. The Sioux District has the next largest increase in weed acreage. Most of the increase in these areas is due to more complete mapping efforts in 2016, many of the weeds were likely present in 2006 although some increase has been due to wildfires and increase in off-highway vehicle use.

Table 5. Acres of weeds in 2006 and 2016, gross area (footprint -no over lapping populations)

Landscape Area	2006 Weed Acreage	2016 Weed Acreage	Infestation Increase
Gallatin, Madison and Beartooth Mtns	14,455	27,503	Two-fold Increase
Bridger, Bangtail and Crazy Mtns	699	4,485	Six-fold Increase
Pryor Mtns	1,007	2,025	Two-fold Increase
Ashland	9,821	16,122	Two-fold Increase
Sioux	1,369	7,477	Five and a half-fold Increase
Total	27,351	57,612[2]	Two-fold Increase

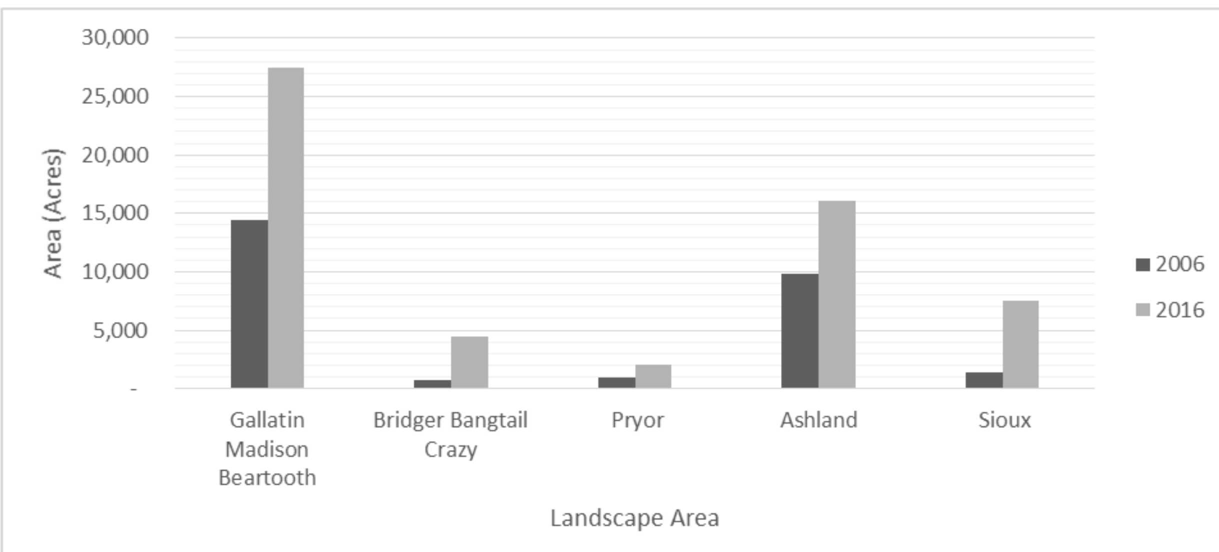

Figure 3. Change in invasive plant species footprint (gross acres infested) between 2006 and 2016

[1] Regulated Plants are not Montana listed noxious weeds. These regulated plants have the potential to have significant negative impacts. The plant may not be intentionally spread or sold other than as a contaminant in agricultural products. The state recommends research, education and prevention to minimize the spread of regulated plants.

[2] This figure pertains to all lands within the proclaimed boundary. Of the 57,612 acres, about 53,527 are on National Forest System lands and the remaining 4,085 acres occur on other ownership lands within the boundary.

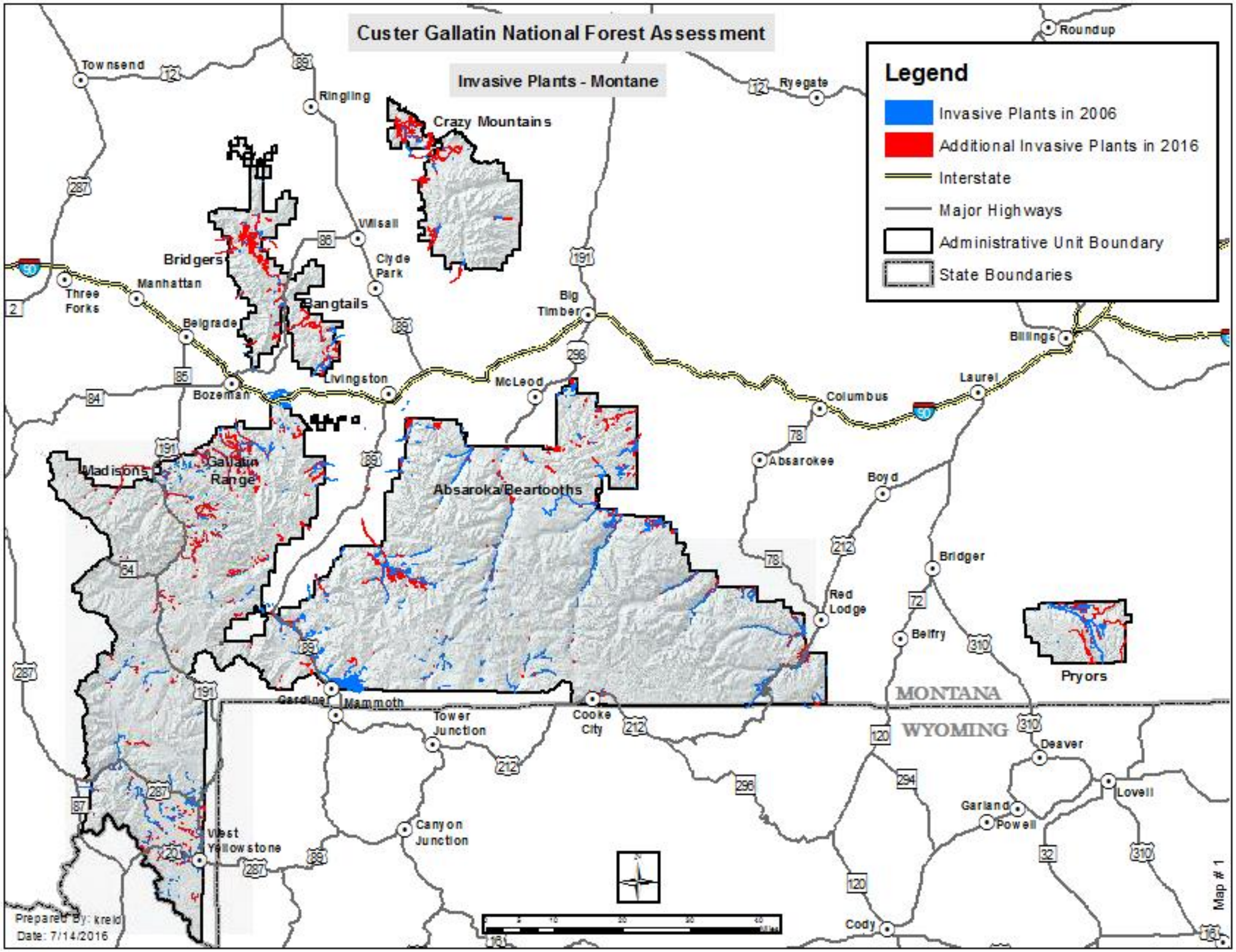

Figure 4. Invasive plant inventory in 2006 (blue) and the additional extent as depicted from 2016 data (red) in montane units

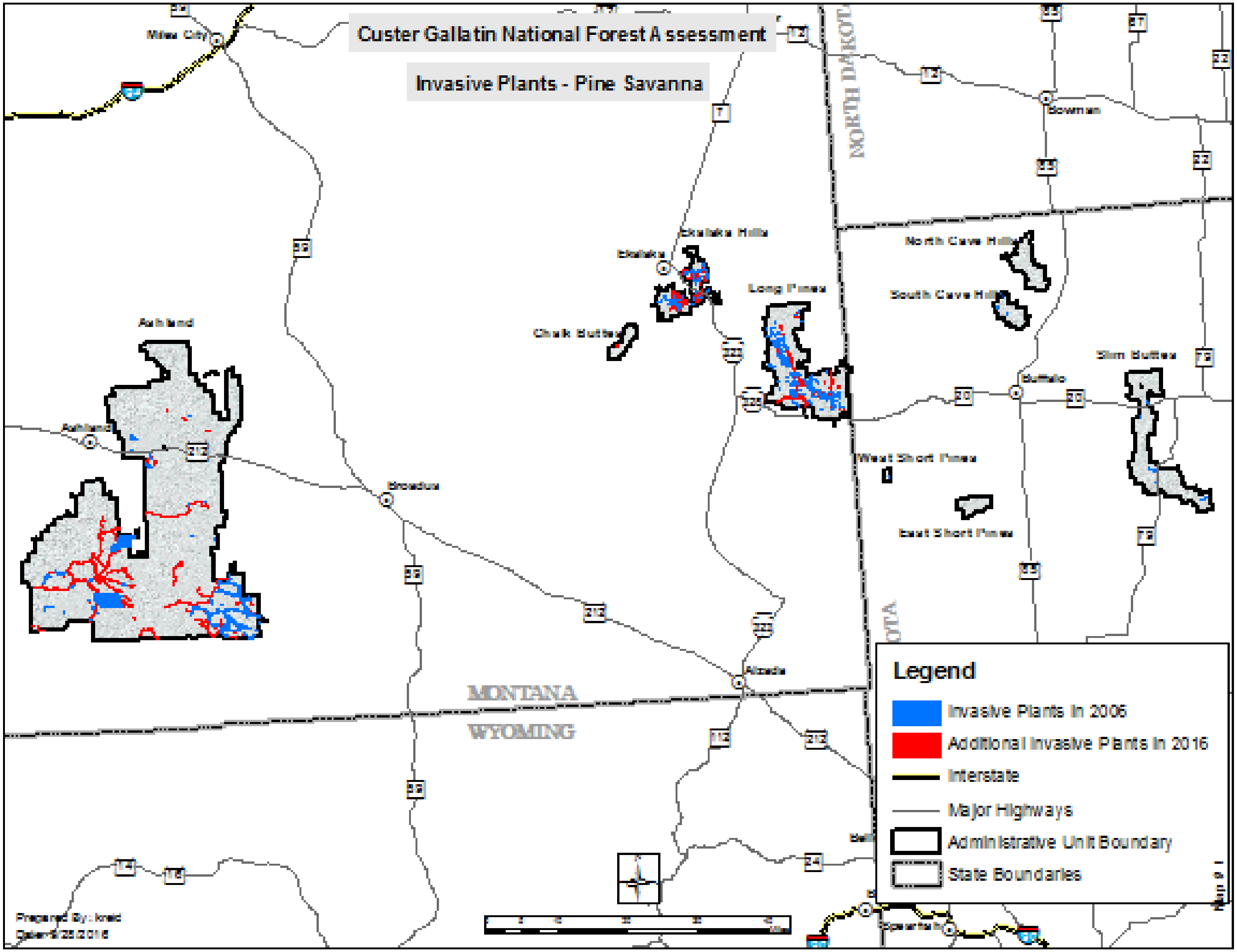

Figure 5. Invasive plant inventory in 2006 (blue) and the additional extent as depicted from 2016 data (red) in pine savanna units

Role of Disturbance and Invasive Plant Species

Disturbance is widely recognized as a primary influence on plant community composition and is frequently implicated in the spread of invasive exotic plants (Hobbs and Humphries 1995). Disturbance is defined as "any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment" (Pickett and White 1985). Parks et al. (2005) examined the patterns of invasive plant diversity in northwest mountain ecoregions and found an overwhelming importance of disturbance in facilitating the establishment of nonnative plants. Disturbances can occur as a result of natural events such as floods, wind events and animals. Disturbance can also result from human activities such as construction of roads and trails, livestock grazing, features common to logging activities such as skid-trails and landings, off-road use of all-terrain vehicles, and other activities Fire suppression efforts can also result in disturbances. Fireline disturbances create suitable conditions for many nonnative species to become established (Parks et al. 2005).

At local scales, nonnative invasive species richness and abundance are generally highest in and around disturbed patches, corridors, and edges such as riparian corridors, transportation corridors and fuel treatments (Benninger-Truax et al. 1992; Gelbard and Belnap 2003; Larson 2003). Buckley et al. (2003) found that features common in logged areas such as skid trails and haul roads are likely to support populations and propagules of nonnative plants. Their research also suggests that haul roads, skid trails and main forest routes serve as primary conduits for entry of introduced species into the interior of managed stands. At regional or landscape scales, richness and abundance of nonnative invasive plants tend to be lower in protected or undeveloped areas than in human-dominated landscapes or landscapes fragmented by human use (Barton et al. 2004). Though, natural disturbance can be a major contributor to increases in invasive species abundance, most of today's weed problems arise from past and present human activities (Hobbs and Humphries 1995).

Local data corroborate the above findings that human use is a key driver to the spread of invasive plants. Most of the mapped weeds on the Custer Gallatin National Forest are located within 2,000 feet of a road. Table 6 summarizes the data from GIS queries that selected all weed infestations within 2,000 feet of a road (all roads including decommissioned roads). This trend was also documented in Yellowstone National Park along roads and trails (Rew 2010).

Table 6. Acres of weed-infested area and percent of infested acres within 2,000 feet of a road

Landscape Area	Total Infested Acres	Infested Acres within 2,000 feet of Roads	Percent of Infested Acres within 2,000 feet of Roads
Gallatin, Madison and Beartooth Mtns	34,766	29,260	84%
Bridger, Bangtail and Crazy Mtns	8,348	8,342	100%
Pryor Mtn	3,046	3,046	100%
Ashland	12,032	12,006	100%
Sioux	5,863	5,771	98 %

Role of Drought and Invasive Plant Species

Droughts are predicted to accelerate the pace of invasion by some nonnative plant species into grasslands, shrublands, and open woodlands. Drought conditions can exacerbate invasions by favoring invasive species over native species, although not all invasive species will be favored. For example, opportunities for invasion are created when drought kills native plants leaving open niches and bare ground (USDA Forest Service 2016).

The ability to manage invasive plants using herbicides could be reduced during periods of drought. To be effective, herbicides must be taken up through the leaves and stems of actively growing, green plants. Herbicides applied to the foliage during periods of drought are usually much less effective than those applied when moisture is adequate (USDA Forest Service 2016)

There is also some evidence that drought can alter the effectiveness of biological control of invasive plants. Historically, drought stress in plants was thought to benefit plant-feeding insects, which suggested that drought could benefit biocontrol using insects. However, studies have found that continuous drought stress in plants negatively affected many insect herbivores, suggesting that biocontrol efficacy could generally be reduced by drought (USDA Forest Service 2016).

Many, not all, non-native invasive plant species will either expand into, or if already established, increase in abundance, particularly in the lower elevation grassland, shrubland, and open woodland communities, regardless of level of disturbance, as these communities become warmer and drier (Halofsky et al. in Press). The rate and magnitude of infestation will likely increase with greater disturbance (Bradley 2008).

Role of Fire and Invasive Plant Species

Although the Custer Gallatin National Forest is attempting to restore historical fire regimes to the landscape, fire can have a detrimental impact to the ecosystem after a fire, depending on the occurrence of invasive species infestations before the fire. Generally speaking, if a fire occurs in a plant community where nonnative plant propagules are abundant or the native species are stressed, then nonnative species are likely to establish and spread in the post-fire environment (Zouhar et al. 2008). From studies conducted in closed-canopy forests in the West (mostly subalpine fir and spruce), it has been observed that nonnative species with easily dispersed seed can infest a burned area where there were no invasive plants before the burn. Some species (like St. John’s wort) tend to die back when the canopy closes after a fire. Other species (like Canada thistle) persist in partially closed canopy conditions. Fire size and burn severity also influence post-burn susceptibility to invasion by nonnative plants. Ferguson and Craig (2010) suggest that invasive plant occurrences after fire generally increase with increasing burn severity.

Some studies suggest that the presence of invasive plants in the landscape changes fire regimes. The most notable is cheatgrass which has been shown to increase fire frequency and severity. Research is emerging that suggests other invasive species may impact fire regimes. For example, Zouhar and others (2008) suggest that dense knapweed infestations may alter fuel characteristics at a given site and thus affect fire regime characteristics such as return interval and severity due to that fact that knapweed does not carry fire as readily as grasses.

Even as fire is considered a factor in modifying sites and leading to suitable conditions for weeds, it can also be used to control weeds to an extent (DiTomaso et al. 2006). Timing in the plant’s phenology is crucial and often cannot be met when considering prescribed burning windows. Annual and biennial species are easier to control than perennial species, and do not need as many fire treatments to impact the seed bank. Perennial species take more treatment and need more than just fire to control the infestation. The intent of controlling an infestation by fire is to kill the seeds as they are still immature on the plant or newly dropped on the ground. Considering the fire-prone nature of the Custer Gallatin National Forest during the time when these plants would need to be burned (mid- to late-summer), fire is not a practical control tactic. It is useful, however, to remove thatch left behind by dead plants to allow herbicide access to fresh shoots at ground level. This burning approach could be conducted during the fall or spring burning windows.

Climate Change and Invasive Plant Species

Multiple studies support the hypothesis that climate change is occurring in one form or another. A local study by Pedersen et al. (2009) examined temperature observations in Montana over the past 100 years. The study found that, on average, very cold temperatures (-64 degrees Fahrenheit and colder) ended 20 days earlier in 2006 than in 1892, and very hot temperatures (more than 90 degrees Fahrenheit) had a three-fold increase in number of days and have extended, on average, 24 days longer in the season. Climate change is more than elevated temperatures across ecosystems. It accounts for an increase in both minimum and maximum temperatures, with daily minimum temperatures rising more rapidly than maximum temperatures (Vose et al. 2005).

The success of invasive plants in native plant communities is highly influenced by factors related to environment (such as temperature, precipitation, and carbon dioxide), disturbance or resource availability, propagule pressure (seeds), and biotic resistance (Pauchard et al. 2009, Poorter and Navas 2003, Eschtruth and Battles 2009). The kind of temperature changes observed, described and projected by several studies over the past decade may have notable effects on native vegetation and invasive plants. Although temperature shifts can alter invasive dynamics, the greatest effect of climate change in biotic communities arises from shifts in maximum and minimum temperatures rather than annual means (Stachowicz et al. 2002). These changes can give invasive species an early season start, resulting in increased growth and recruitment relative to native species (Traill et al. 2010). The increase in carbon dioxide in the atmosphere may also affect plant metabolism because carbon dioxide is the main requirement for photosynthesis and oxygen production. Studies have shown that elevated carbon dioxide levels can lead to a reduction in herbicide efficacy (Archambault 2001, Ziska and Teasdale 2000). Reduced treatment effectiveness coupled with the potential for increased opportunities for growth and vigor as a result of changes in precipitation levels, carbon dioxide, and temperature increases the potential for invasive plants to gain an even greater advantage over native species.

Other effects include shifts in distribution. The effects of climate change on species' distributions are likely to be complex given the potentially differing climatic controls over upper and lower distribution limits (Harsch and Lambers 2014). Some studies predict a movement in some invasive plant species range closer to the poles or upward in elevation (Chen et al. 2011). Pauchard et al. (2009) suggest that the threat posed to high-elevation biodiversity by invasive plant species is likely to increase because of globalization and climate change. Other studies, such as Harsch and Lambers (2014), suggest that distribution shifts in response to recent climate change could occur in either direction (upward or downward).

Fire is another factor potentially affected by climate change. When combined with climate change, fire/invasive plant relationships may be exacerbated leading to greater invasive species populations and spread. Other disturbances or shifts in historical patterns may be affected by climate change and in turn affect the spread of invasive species. As the agency responds to climate change by new, different, or more land and vegetation management actions, those disturbances could provide suitable conditions for invasive plants. Conversely, appropriately planned and implemented restoration treatments following fire events could improve the resistance and resilience of plant communities to invasive plant invasion.

Historical Conditions and Trends

Many invasions of nonnative plants established in the Northwest between 1850 and 1920 during the region's great influx of agrarian settlers (Parks et al. 2005). Initial introductions were associated with early trade vessels, which brought grain and livestock shipments contaminated with foreign seeds, as well as freighters that dumped ore deposits and ship ballasts containing foreign plant material onto shores and around docks at and near port cities (Parks et al. 2005). Invasive plants have continued to increase and spread since introduction. According to Westbrooks (1998), invasive plants have more than quadrupled their range between 1985 and 1995 and constitute from 8 to 47 percent of the total flora of most states. As of 1996, invasive nonnative species had invaded at least 17 million acres of Federal lands in the West (USDA Forest Service 1998). Similar increases in infested acres have been experienced at the local scale on the Custer Gallatin National Forest, where over the last 10 years, weed infestations have doubled.

Topography has been shown to influence invasive plant spread. Mountains, in general, have fewer nonnative plant introductions relative to lowland areas, due in part to the large amount of public land and limited access to these areas. Nonetheless, plant invasions occur in the mountains, and land-use and land-cover change has undoubtedly been the underpinning for the successful establishment of invasive plant species (Parks et al. 2005).

Locally, the rate of establishment and spread has been influenced primarily by road construction and road use for recreation, timber harvest, grazing and other related activities. Most of these activities began on a large scale in the 1950s and 1960s on the Custer Gallatin National Forest. A majority of recorded infestations are associated with disturbances. According to current inventory data, approximately 84 to 100 percent of the current inventoried invasive plant infestations occur within 2,000 feet of major transportation routes (system roads and trails). Many roadless areas remain relatively weed-free because of the presence of healthy undisturbed native plant communities where few vectors exist to spread invasive species.

Expected Trend

Weed spread vectors include wind, water, transportation routes, wildfire effects, and activities associated with timber production, livestock use, wildlife use, and recreational use. These events or uses continue to provide endpoints for introduction and subsequent seed dispersal and disturbance that enhances germination and establishment of nonnative plants. As of 1996, invasive plant species had invaded 6 to 7 million acres of National Forest Service lands with an observed annual rate of spread of 8 to 12 percent (USDA Forest Service 1998). It is predicted that climate change trends will continue into the reasonably foreseeable future.

Of equal importance is the current and predicted continuation of globalization. For hundreds of years, humans have been introducing plants, animals, and other organisms around the world, in a relatively slow process of globalizing the Earth's biota. More recently, the pace of this process has increased with modem trade, travel, and technology, so that biological invasions have become a consequence of globalization. Globalization facilitates and intensifies the spread of invasive alien species (Meyerson and Mooney 2007). As a result, the extent and density of invasive plant infestations as well as the number of invasive plant species has the potential to increase. Assuming that the national average annual rate of spread of 8 to 12 percent applies, there is potential for an increase in invasive plant footprint at a rate of up to approximately 4,600 to 6,900 acres per year. Additional data and monitoring is needed to determine the actual rate of spread on the Custer Gallatin National Forest.

Habitat characteristics are unquestionably important predictors of susceptibility to invasion by invasive plants. Stohlgren et al. (2002) studies in Montana, South Dakota, Minnesota, Wyoming, and Colorado found that in general, habitats in north central United States with high native species richness were more heavily invaded than species in poor habitats, low-elevation areas were more invaded than high-elevation areas, and riparian zones were more invaded than nearby upland sites. They also found that nonnative plant species thrive on the same resources (high light, nitrogen, and water) as native plant species.

The rate of future trends will be dependent on land-use and land-cover changes and ultimately how land managers respond to those changes. The future potential trend for invasive plant infestations can be addressed through invasive plant management programs but may be inhibited by future budgetary and personnel constraints at the local, regional and national levels. Hobbs and Humphries (1995) suggest that much of the plant invasion problem stems from socioeconomic rather than ecological factors.

Information Needs

Forest Plan Information Needs: None identified.

Long-term Information Needs: An updated weed inventory is needed to provide a more accurate description of the invasive weed population. Due to limited funding, weed inventories often occur if time allows and if accessible. Without an updated inventory, the assessment in this report probably understates the true infestation level. Without improved inventory the magnitude of the problem remains uncertain, and that uncertainty limits the ability to develop an effective management strategy. Land managers should develop weed strategies that are both ecologically effective and economically justified. A recent study indicated that the most effective management strategy is to focus on early detection and small infestation control strategies, and not on large infestations (Frid et. al. 2013). An updated inventory would allow for management practices that focus on early detection and treatment of small infestations.

Key Findings

- There is now a footprint of about 58,000 acres of weeds on the Custer Gallatin National Forest. Annual weed treatment ranges from 3,000 to 4,000 acres.
- Inventoried acreage infested by invasive plants has doubled over the past 10 years.
- There are many vectors of weed spread, but human activity is a primary cause, especially along travel routes.
- While about 53 percent of the assessment area is vulnerable to weed invasion in grasslands, shrublands, riparian, and open woodlands, many acres of vulnerable habitat are still weed free. One of the key priorities for the invasive species program is maintenance of weed-free areas.
- Many, not all, non-native, invasive plant species will either expand into, or if already established, increase in abundance, particularly in the lower elevation grassland, shrubland, and open woodland communities, regardless of level of disturbance, as these communities become warmer and drier. The rate and magnitude of infestation will likely increase with greater disturbance.

- Future Custer Gallatin National Forest management must do more to emphasize prevention of weed spread, weed treatment, and must incorporate weed management responsibility and accountability into all resource areas.
- There is a need for controlling the introduction and spread of noxious weed species, including direction that would minimize the spread of weeds that may establish or increase as a result of management activities and decisions.

References

Archambault, D.J. X. Li, D. Robinson, J.T. O'Donovan, K.K. Klein. 2001. The Effects of Eleveated Co2 and Temperature on Herbicide Efficacy and Weed/Crop. Final Report Prepared for the Pine Savanna Adaptation Research Collaborative. Alberta.

Balch, J.K., B.A. Bradley, C.M. D'Antonio, and J. Gomez-Dans. 2012. Introduced annual grass increases regional fire activity across the arid western USA. Global Change Biology Volume 19, Issue 1 2013.

Benninger-Traux, M., J.L. Vankat, and R.L. Schaefer. 1992. Trail corridors as habitat and conduits for movement of plant species in Rocky Mountain National Park, Colorado, USA. Landscape Ecology. 6: 269-278.

Bradley, B.A., M. Oppenheimer, and D.S. Wilcove. 2008. Global Change Biology. Vol 15(6) 1511-1521.

Buckley, D.S. T.R. Crow, E.A Nauertz, K.E. Schulz. 2003. Influence of skid trails and haul roads on understory plant richness and composition in managed forest landscapes in Upper Michigan, USA. Forest Ecology and Management 175 (2003) 509-520.

Chen, I.C., J.K. Hill, R. Ohlemueller, D.B. Roy, and C.D. Thomas. 2011. Rapid range shifts of species associated with high levels of climate warming. Science, 333: 1024-1026.

Clark, J., 2003. Invasive Plant Prevention Guidelines. Center for Invasive Plant Management. Bozeman, MT, 15p. Web. 31 Dec. 2014 http://www.weedcenter.org .

DiTomaso, J.M., Brooks, M.L., Allen, E.B., Minnich, R., Rice, P.M., 2006. Control of Invasive Weeds with Prescribed Burning. Weed Technology. 20(2): 535-548.

Eschtruth, A.K., Battles, J.T., 2009. Assessing the Relative Importance of Disturbance, Herbivory, Diversity, and Propagule Pressure in Exotic Plant Invasion. Ecological Monographs. 79(2): 265-280.

Executive order 13112. 1999 Feb. 3. Invasive Species. Available online at: http://www.invasivespeciesinfo.gov/laws/execorder.shtml.

Ferguson, D.E., and C.L., Craig. 2010. Response of Six Non-Native Invasive Plant Species to Wildfires in the Northern Rocky Mountains, USA. Res. Pap. RMRS-RP-78 Fort Collins, Co: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 12 p.

Frid, L., D. Hanna, N. Korb, B. Bauer, K. Bryan, B. Martin and B, Holzer. 2013. Evaluating Alternative Weed Management Strategies for Three Montana Landscapes. Invasive Plant Science and Management 6(1):48-59.

Gelbard, J.L., Belnap, J., 2003. Roads as Conduits for Exotic Plant Invasions in a Semiarid Landscape. Conservation Biology. 17(2): 420-432.

Halofsky, J.E., D.L. Peterson, S.K. Dante, and L. Hoang (eds.). 2016. Climate change vulnerability and adaptation in the Northern Rocky Mountains. USDA Forest Service General Technical Report RMRS-GTR-xxx. Rocky Mountain Research Station, Fort Collins, CO (in press).

Harsch, M.A. and J. H. Ris Lambers 2014. Species distributions shift downward across western North America. Global Change Biology (2014), doi: 10.1111/gcb.12697.

Hobbs, R.J., Humphries, S.E., 1995. An Integrated Approach to the Ecology and Management of Plant Invasions. Conservation Biology. 9(4): 761-770.

Hoffman, T. 2016 Personal Conversation

Kohl, M.T., M.Hebblewhite, S.M. Cleveland, and R.M. Callaway. 2012. Forage Value of Invasive Species to the Diet of Rocky Mountain Elk. Society of Range Management 34(2): 24-28

Lacey,J.R,,B.M. Clayton , and J.R. Lane. 1989. Influence of Spotted Knapweed (*Centaurea maculosa*) on Surface Runoff and Sediment Yield. Weed Technology, 3:627-631.

Larson, D.L., 2003. Native weeds and exotic plants: relationships to disturbance in mixed-grass Pine Savanna. Plant Ecology. 169: 317-333.

Mantas, Maria, 2003, "Evaluation Risk to Native Plant Communities from Selected Exotic Plant Species"

Meyerson, L.A., Mooney, H.A., 2007. Invasive Alien Species in an Era of Globalization. Frontiers in Ecology and the Environment. 5(4): 199-208.

Olson, B.E.1999 Impacts of Noxious Weeds on Ecologic and Economic Systems. Published in Biology and Management of Noxious Rangeland Weeds by R.L. Sheley and J.K. Petroff.

Parks, C.G., Rodosevich, S.R., Endress, B.A., Naylor, B.J. Anzinger, D., Rew, L.J., Maxwell, B.D., Dwire, K.A., 2005. Natural and land-use history of Northwest mountain ecoregions (USA) in relation to patterns of plant invasions. Perspectives in Plant Ecology, Evolution and Systematics. 7: 137-158.

Pauchard, A., C. Kueffer, H. Dietz, C.C. Daehler, J. Alexander, P.J. Edwards, J.R. Arevalo, L.A. Cavieres, A. Guisan, S. Haider, G. Jakobs, K. McDougall, C.I. Millear, B.J. Naylor, C.G. Parks, L.L. Rew, and T. Seipel. 2009. Ain't no mountain high enough: plant invasions reaching new elevations. Frontiers in Ecology and the Environment. 7, doi,10.1890/080072.

Pederson, G.T., L.J. Graumlich, D.B. Fagre, T. Kipfer, and C.C. Muhlfeld. 2010. A century of climate and ecosystem change in Western Montana: What do recent temperature trends portend? Climate Change (2010) 98:133-154. DOI 10.1007/s10584-009-9642-y.

Penn Stat. 2015. Invasive grass fuels increased fire activity in the West. Science Daily. www.sciencedaily.com/releases/2012/12/12120513257.htm

Pickett, S.T.A., and White, P.S. 1985. The Ecology of Natural Disturbance and Patch Dynamics. Academic Press, New York.

Poorter, H., Navas, M., 2003. Plant Growth and Competition at Elevated CO_2: Winners, losers and Functional Groups. New Phytologist. 157(2): 175-198.

Rew, L. 2010. Stratified Random Sampling Method. http://www.weedcenter.org/education/docs/lRew_stratified_03Feb10.pdf

Robinson, M. 2002 Hydrilla: An Invasive Aquatic Plant.

Sheley, R., C.A. Duncan, M. B. Halstvedt and J. S. Jacobs. 2000. Spotted knapweed and grass response to herbicide treatments. Journal of Range Management 53(2), March

Sheley, R., M. Manoukian and G. Marks. 2011. Preventing Noxious Weed Invasions. Montana State University Extension MontGuide MT199517AG.

Stachowicz, J.J., Terwin, J.R., Whitlatch, R.B. Osman, R.W., 2002. Linking climate change and biological invasions: Ocean warming facilitates nonindigenous species invasions. Proc. Natl. Acad. Sci. USA 99, 15 497–15 500. (doi:10.1073/pnas.242437499)

Stohlgren, T.J., G.W. Chong, L.D. Schell, K.A. Rimar, Y. Otsuki, M. Lee, M.A. Kalkhan, and C.A. Villa 2002. Assessing Vulnerability to Invasion by Nonnative Plant Species at Multiple Spatial Scales. Environmental Management 29(4): 566-577.

Thorpe, A.S,, V. Archer and T.H. Deluca. 2006. The invasive forb, Centaurea maculosa, increases phosphorus availability in Montana grasslands. Applied Soil Ecology. 32: 118-122.

Traill, Lochran W. Barry W. Brook a, Richard R. Frankham b, Corey J.A. Bradshaw. 2010. Pragmatic population viability targets in a rapidly changing world. Biological Conservation 143 (2010) 28–34.

U.S. Department of Agriculture, APHIS. 2001. Future Trends in Agricultural Trade.

U.S. Department of Agriculture, Forest Service. 1986a. Custer National Forest Plan.

U.S. Department of Agriculture, Forest Service. 1986b. Gallatin National Forest Plan.

U.S. Department of Agriculture, Forest Service.1998. Stemming the Invasive Tide: FS Strategy for Management of Noxious and Nonnative Plant Mgmt. pp. 29

UF/IFAS. University of Florida, Plant Management in Florida Water. http://plants.ifas.ufl.edu/manage/overview -of-florida-waters/water-quality/photosynthesis/

United States Department of Agriculture, Forest Service. 2016. Effects of Drought on Forests and Rangelands in the United States: A Comprehensive Science Synthesis. Gen. Tech. Rpt WO-93b. 302p.

USDA Forest Service Custer National Forest 2006 Weed Management Final EIS

USDA Forest Service Gallatin National Forest 2005 Final EIS Noxious Invasive Weed Treatment Project

USDA Forest Service Manual (FSM) 2080 Noxious Weed Management

Vose, Russell S., David R. Easterling, and Byron Gleason. Maximum and Minimum Temperature Trends for the Globe: An Update through 2004. NOAA National Climatic Data Center, Asheville, North Carolina.

Westbrooks, R. 1998. Invasive plants, changing the landscape of America: Fact book. Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW), Washington, D.C. 109 pp.

Ziska, Lewis H. and John R. Teasdale 2000. Sustained growth and increased tolerance to glyphosate observed in a C3 perennial weed, quackgrass (Elytrigia repens), grown at elevated carbon dioxide. Aust. J. Plant Physiol., 27, 159–166

Appendix A - Maps of Vulnerable Habitat

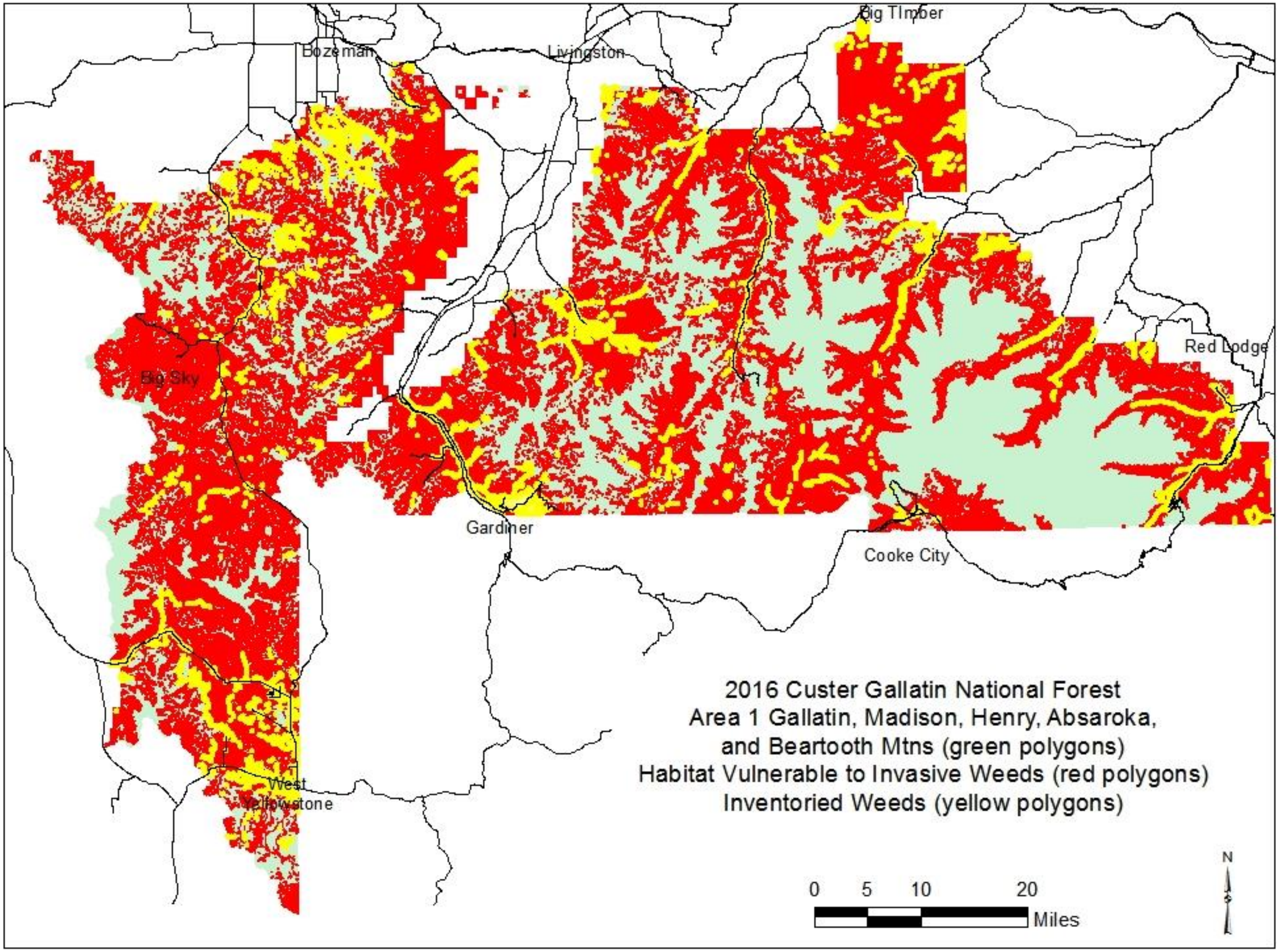

Figure A-1. Gallatin, Madison, Henry, Absaroka, and Beartooth Mountains habitat vulnerable to invasive plants

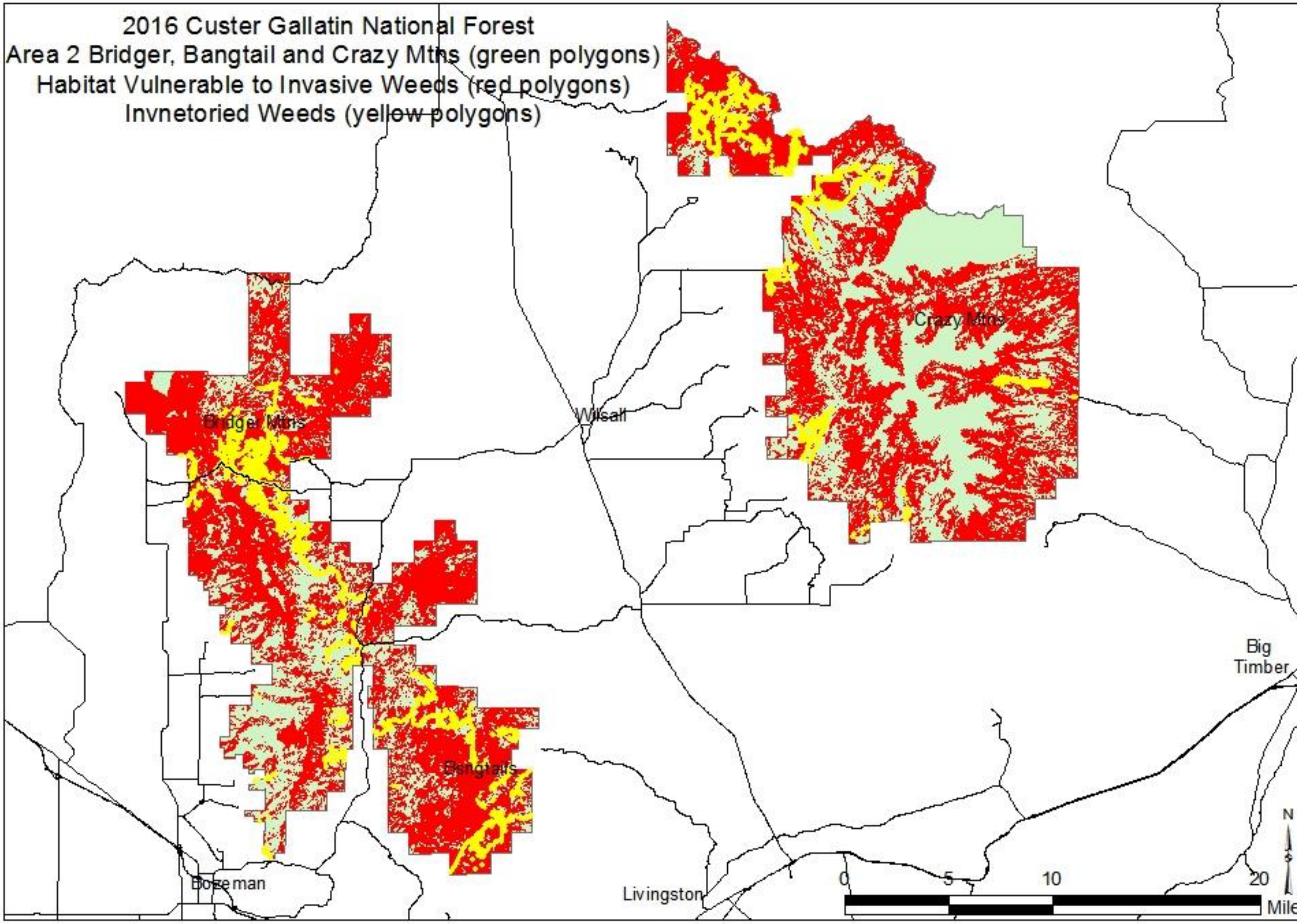

Figure A-2. Bridger, Bangtail and Crazy Mountains habitat vulnerable to invasive plants

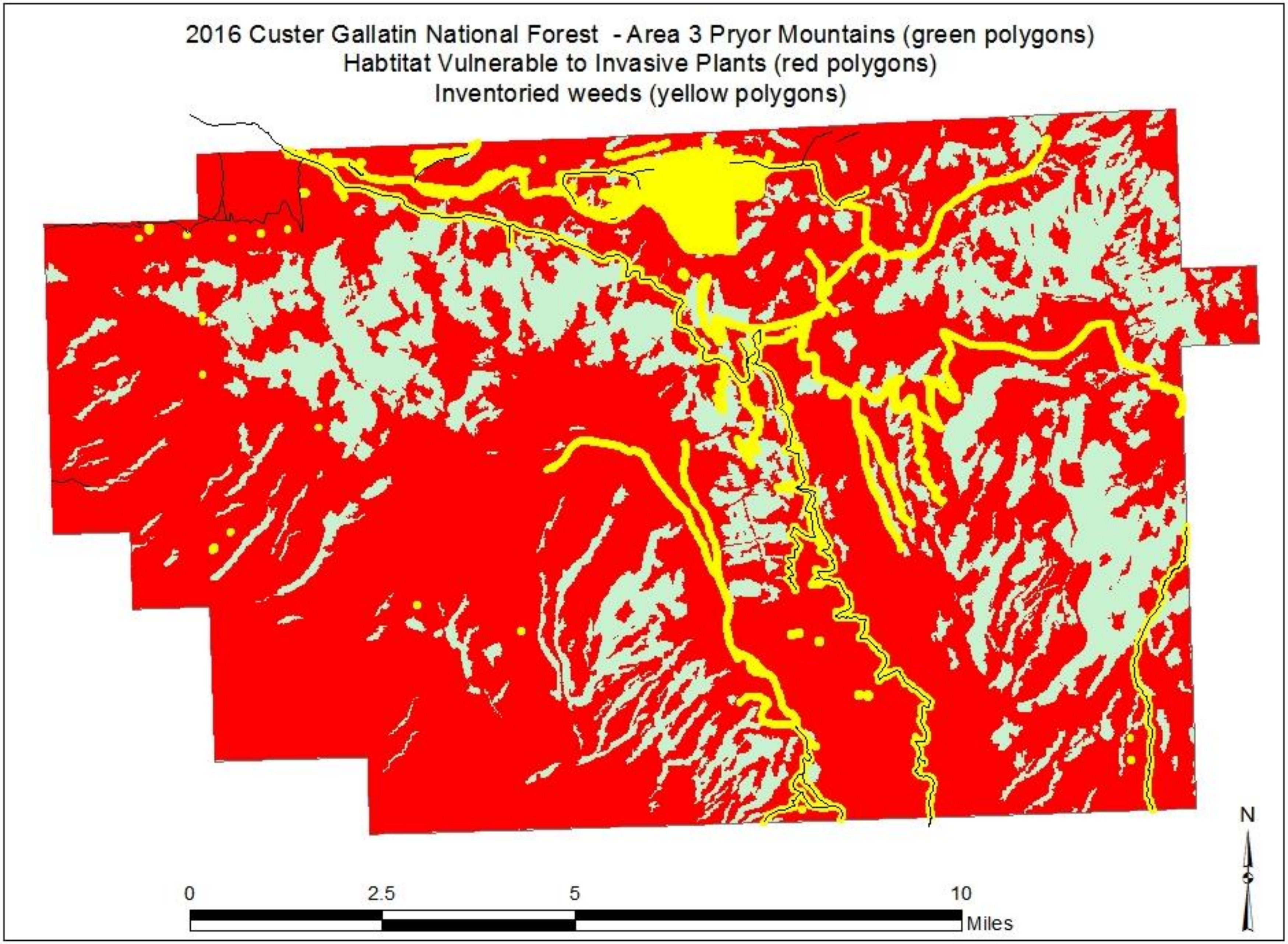

Figure A-3. Pryor Mountains habitat vulnerable to invasive plants

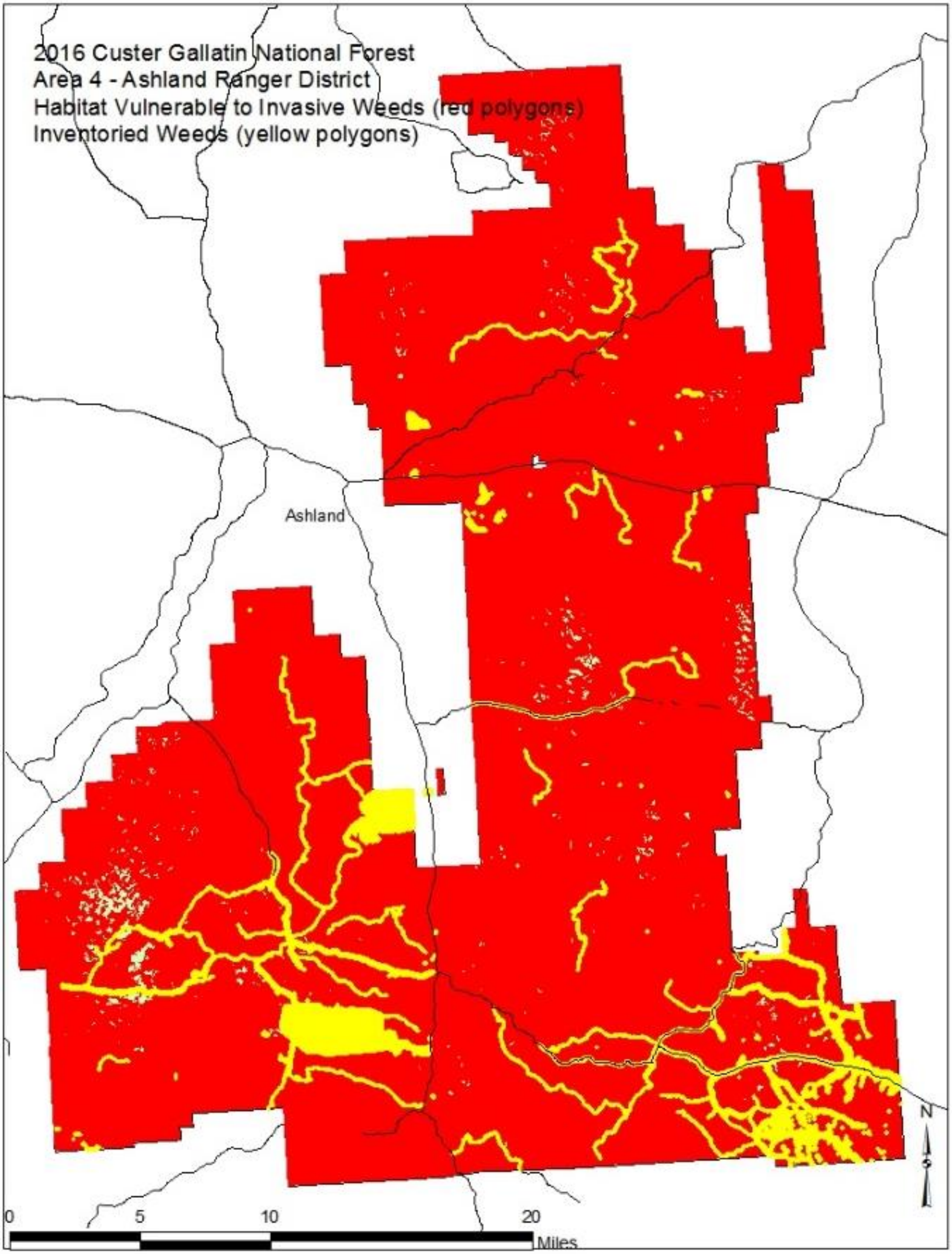

Figure A-4. Ashland Ranger District habitat vulnerable to invasive weeds

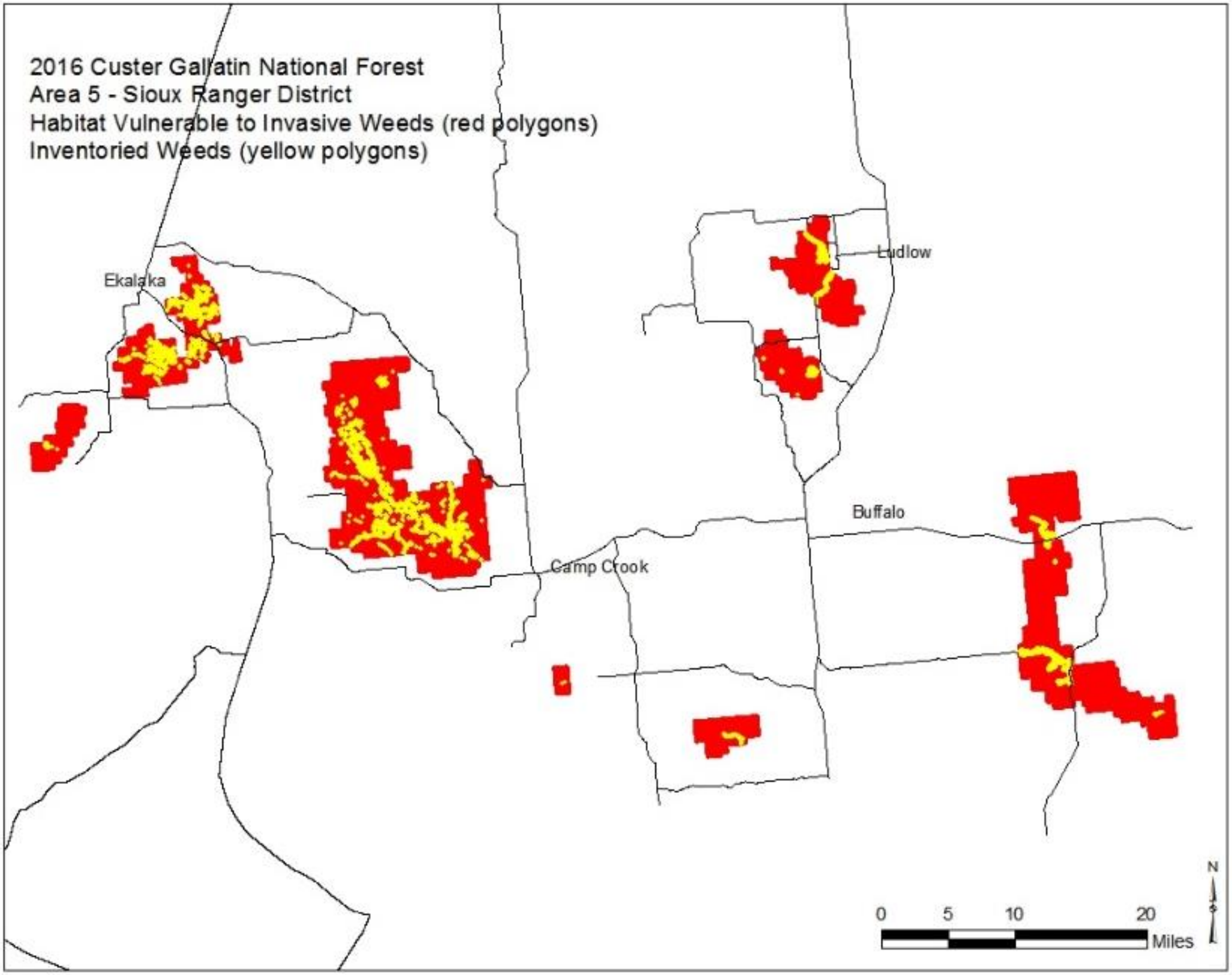

Figure A-5. Sioux Ranger District habitat vulnerable to invasive plants

Appendix B - 2016 Noxious Weed Species List

Montana Noxious Weed List

Priority 1A – Weeds not present or with very limited presence

- Yellow starthistle (*Centaurea solstilialis*)
- Dyer's woad (*Isatis tinctoria*)
- Common reed *(Phragmites australis)*

Priority 1B – Weeds with very limited presence

- Japanese knotweed complex
- Purple loosestrife *(Lythrum salicaria)*
- Rush skeletonweed *(Chondrilla juncea)*
- Scotch broom *(Cytisus scoparius)*

Priority 2A – Weeds common in isolated areas

- Tansy ragwort *(Senecio jacobaea)*
- Meadow hawkweed complex
- Orange hawkweed (*Hieracium aurantiacum)*
- Tall buttercup (*Ranunculus acris)*
- Perennial pepperweed *(Lepidium latifolium)*
- Blueweed *(Echium vulgare)*
- Eurasian watermilfoil *(Myriophyllum spicatum)*
- Flowering rush *(Butomus umbellatus)*

Priority 2B - Weeds are abundant and widespread

- Canada thistle *(Cirsium arvense)*
- Field bindweed *(Convolulus arvensis)*
- Leafy spurge *(Euphorbia esula)*
- Whitetop (*Cardaria draba)*
- Russian knapweed (*Acroptilon repens)*
- Spotted knapweed *(Centaurea stoebe)*
- Diffuse knapweed *(Centaurea diffusa)*
- Dalmatian toadflax *(Linaria dalmatica)*
- St. John's wort (*Hypericum perforatum)*
- Sulfur cinquefoil (*Potentilla recta)*
- Common Tansy *(Tanacetum vulgare)*
- Oxeye daisy (*Leucanthemum vulgare*)
- Hounds-tongue *(Cynoglossum officinale)*
- Yellow toadflax (*Linaria vulgaris)*
- Saltcedar (*Tamarix* spp.)
- Curlyleaf pondweed (*Potamogeton crispus*)
- Hoary alyssum (*Berteroa incana*)

Priority 4 Regulated Plants – Not legally Noxious Weeds but may not intentionally spread the plants

- Cheat grass (*Bromus tectorum*)
  - Hydrilla (*Hydrilla verticillata*)
  - Russian olive (*Elaeagnus angustifolia*)
  - Brazialian waterweed (*Egeria densa*)
  - Parrot feather watermilfoil (*Myriophyllum aquaticum*)

South Dakota Noxious Weed List (if not listed above)

- Plumless thistle *(Carduus acanthoides)*
- Common crupina *(Crupina vulgaris)*
- Dodder (*Cuscuta L.)*
- Multiflora rose (*Rosa multiflora)*
- Perennial sowthitsle (*Sonchus arvensis)*
- Johnsongrass (*Sorghum halepense)*

Additional County and Forest Weed List

- Absinthum (*Artemisia absinthium*)
- Nodding plumeless thistle *(Carduuss nutan)*
- Bull thistle (*Cirsium vulgare)*
- Poison hemlock (*Conium maculatum*)
- Black henbane (*Hyposcyamus niger)*
- Common mullein *(Verbascum thapsus*)

Appendix C – Noxious Weeds in Special Areas

2016 List of Invasive Weeds for Wilderness, Recommended Wilderness, Roadless, Research Natural Areas and Botanical Special Interest Areas

Weeds in Special Areas by Species (if 0 acres then weeds are present but less than 1 acre)

Table C-1. Weeds in the Wilderness

Wilderness	Gross Acres	Net Acres based on % Infested
Absaroka-Beartooth Wilderness	**3,168**	**2123**
bull thistle	155	24
butter and eggs	46	13
Canada thistle	1,397	907
cheatgrass	130	130
common mullein	9	9
common tansy	62	11
Dalmatian toadflax	42	15
houndstongue	598	474
hoary alyssum	6	2
leafy spurge	8	2
nodding plumeless thistle	331	256
orange hawkweed	19	17
oxeye daisy	49	45
spotted knapweed	268	202
sulphur cinquefoil	0	0
tall buttercup	47	18
Lee Metcalf Wilderness	**61**	**56**
Canada thistle	55	54
houndstongue	5	1
nodding plumeless thistle	0	0
orange hawkweed	1	0
sulphur cinquefoil	0	0
Grand Total	**3,229**	**2,179**

Table C-2. Weeds in roadless and Forest Service recommended wilderness

Roadless and Forest Service Recommended Wilderness	Gross Acres	Net Acres based on % Infested
Beartooth	**0**	**0**
Canada thistle	0	0
Black Butte	**14**	**11**
Canada thistle	5	5
houndstongue	4	4
orange hawkweed	5	2
tamarisk	0	0
Bridger	**238**	**92**
Canada thistle	64	22
common St. Johnswort	9	9
common tansy	3	0
houndstongue	44	9
hoary alyssum	1	1
leafy spurge	28	28
nodding plumeless thistle	42	9
oxeye daisy	21	3
spotted knapweed	27	11
Burnt Mountain	**27**	**14**
spotted knapweed	27	14
Cabin Creek Wildlife Management Area	**41**	**41**
Canada thistle	41	41
oxeye daisy	0	0
Chico Peak	**134**	**44**
bull thistle	9	1
Canada thistle	25	18
common St. Johnswort	1	1
houndstongue	73	7
nodding plumeless thistle	25	17
spotted knapweed	0	0

Roadless and Forest Service Recommended Wilderness	Gross Acres	Net Acres based on % Infested
Crazy Mountain	**1134**	**525**
bull thistle	112	21
butter and eggs	152	73
Canada thistle	252	128
houndstongue	221	92
leafy spurge	13	1
nodding plumeless thistle	262	132
orange hawkweed	0	0
oxeye daisy	22	22
spotted knapweed	78	36
sulphur cinquefoil	22	22
Dry Canyon	**3**	**3**
hoary alyssum	3	3
Fishtail Saddleback	**1**	**1**
Canada thistle	1	1
Gallatin Fringe	**115**	**65**
bull thistle	2	0
Canada thistle	50	35
cheatgrass	16	15
common mullein	0	0
common tansy	0	0
Dalmatian toadflax	0	0
houndstongue	28	8
hoary alyssum	1	1
leafy spurge	1	0
nodding plumeless thistle	0	0
oxeye daisy	13	2
spotted knapweed	3	2
Hyalite - Porcupine - Buffalo Horn Wilderness Study Area	**379**	**186**
bull thistle	4	1
butter and eggs	9	9
Canada thistle	139	69
cheatgrass	0	0
common mullein	23	15
houndstongue	130	59
meadow hawkweed	1	0

Roadless and Forest Service Recommended Wilderness	Gross Acres	Net Acres based on % Infested
nodding plumeless thistle	32	17
orange hawkweed	3	0
oxeye daisy	8	1
pennycress	0	0
spotted knapweed	29	14
whitetop	0	0
King Mountain	**11**	**9**
spotted knapweed	11	9
Line Creek Plateau	**34**	**34**
spotted knapweed	34	34
Lionhead	**104**	**45**
bull thistle	1	0
Canada thistle	12	2
common mullein	5	0
common tansy	0	0
diffuse knapweed	1	1
golden chamomile	2	1
houndstongue	36	18
hoary alyssum	16	4
nodding plumeless thistle	3	0
orange hawkweed	0	0
oxeye daisy	11	4
poison hemlock	0	0
spotted knapweed	18	14
whitetop	0	0
Lionhead Recommended	**10**	**3**
Canada thistle	0	0
houndstongue	1	0
hoary alyssum	6	1
nodding plumeless thistle	0	0
orange hawkweed	0	0
poison hemlock	1	0
spotted knapweed	2	2
Lost Water Canyon Recommended	**17**	**17**
spotted knapweed	17	17
Madison	**372**	**276**

Roadless and Forest Service Recommended Wilderness	Gross Acres	Net Acres based on % Infested
butter and eggs	130	120
Canada thistle	71	53
cheatgrass	1	1
common mullein	4	4
common tansy	0	0
field scabiosa	0	0
houndstongue	49	34
hoary alyssum	14	9
leafy spurge	0	0
nodding plumeless thistle	59	16
oxeye daisy	11	10
spotted knapweed	32	28
tall buttercup	0	0
whitetop	0	0
Mt. Gmt Area H	**0**	**0**
Canada thistle	0	0
meadow hawkweed	0	0
Mystic	0	0
Canada thistle	0	0
North Absaroka	8981	5653
black henbane	127	51
broadleaved pepperweed	4	1
bull thistle	394	244
butter and eggs	161	144
Canada thistle	1802	1142
cheatgrass	882	882
common mullein	150	144
common tansy	149	55

Roadless and Forest Service Recommended Wilderness	Gross Acres	Net Acres based on % Infested
Dalmatian toadflax	1138	120
houndstongue	1978	1232
hoary alyssum	6	3
leafy spurge	221	221
nodding plumeless thistle	873	574
orange hawkweed	6	6
oxeye daisy	12	5
spotted knapweed	1074	826
sulphur cinquefoil	4	3
tall buttercup	0	0
Red Lodge Creek Hellroaring	**466**	**408**
absinthium	0	0
Canada thistle	18	3
leafy spurge	7	2
spotted knapweed	441	403
Reef	**26**	**14**
Canada thistle	12	9
houndstongue	12	4
hoary alyssum	1	1
nodding plumeless thistle	0	0
spotted knapweed	1	0
tall buttercup	0	0
Rock Creek	**1**	**0**
Canada thistle	1	0
spotted knapweed	1	0
Tongue River Breaks	**0**	**0**
tamarisk	0	0
Grand Total	**12108**	**7440**

Table C-3. Weeds in research natural areas (RNA)

Research Natural Areas	Gross Acres	Net Acres based % Infested
East Fork Mill Creek RNA	**10**	**5**
Canada thistle	1	1
houndstongue	2	2
oxeye daisy	0	0
spotted knapweed	6	2
Line Creek RNA	**8**	**8**
Canada thistle	4	4
spotted knapweed	4	4
Lost Water Canyon RNA	**1**	**1**
spotted knapweed	1	1
Obsidian Sands RNA	0	0
butter and eggs	0	0
Sliding Mountain RNA	**2**	**2**
Canada thistle	1	1
Dalmatian toadflax	1	1
Grand Total	**20**	**16**

Table C-4. Weeds in special interest areas (SIA)

Special Interest Areas	Gross Acres	Net Acres based on % Infested
Bangtail SIA	**467**	**447**
Canada thistle	90	80
common mullein	60	60
common tansy	0	0
houndstongue	161	155
nodding plumeless thistle	152	148
spotted knapweed	4	3
Black Sand Spring SIA	**2**	**1**
butter and eggs	1	1
Canada thistle	0	0
hoary alyssum	0	0
spotted knapweed	0	0
Grand Total	**469**	**447**